Constraining the lightning NOx source estimate over North America using TES, NLDN data and the GEOS-Chem model

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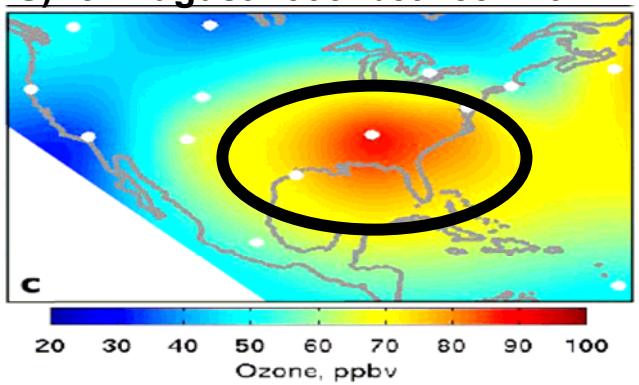
Motivations

- **Strength of the lightning NOx emissions remain largely uncertain.**
  (Recent overview : 5 TgN/yr +/-3 TgN/yr (or +/- 60%) **Schumann and Huntrieser [2007]**).

- **Understanding this source is critical to assess**
  - **impact of future NOx changes on ozone in the upper troposphere**
  - **feedback between climate change and lightning.**

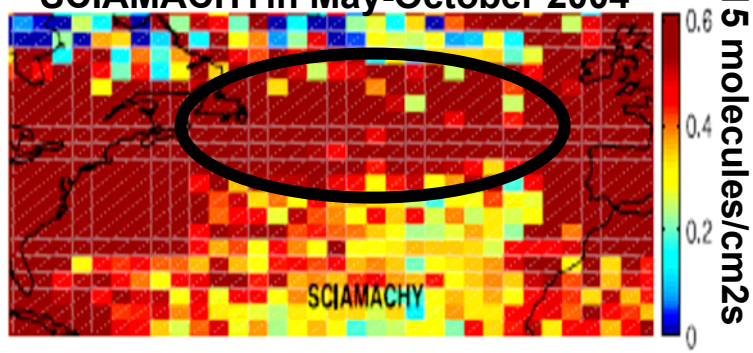
- **Over the USA, lightning NOx contribute to**
  - **Summertime upper tropospheric ozone maximum**
  - **pollution exported from North America**

Tropospheric O_3 vmr from ozonesondes (IONS) for August 2006 between 10-11 km.



Cooper et al. (2007)

Tropospheric NO2 columns from SCIAMACHYin May-October 2004



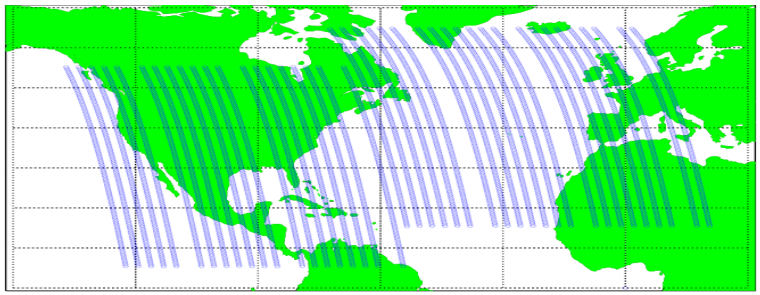
Martin et al. (2005)

Methodology

- **Compute 5-days forward trajectories from the 1 x 1 gridded and hourly averaged flashes from National Lightning Detection Network for July and August 2006** (National Lightning Detection Network) using HYSPLIT model driven by the GDAS meteorology. Trajectories initialized at 8 km.

- **Look for the intersection of trajectories with the TES track**
  criteria for coincidences : +/- 1 degree lat/lon, +/- 1 hour

Coverage of TES Step and Stares (16 days)



144 Step and Stare and 26 Global Survey between 4 July and 21 August 2006

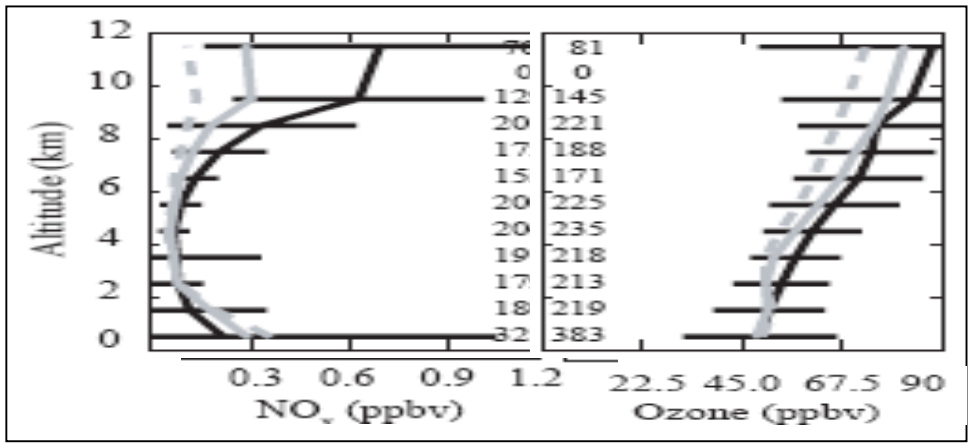
- **Run the Global 3D CTM GEOS-Chem (v7-04-09) for Jan-August 2006**, sample model along the TES track, apply the TES operator.

- **Compare TES and GEOS-Chem prediction** for the cases where lightning influences were found in the TES data.

- **Sensitivity studies to the lightning source strength and distribution** were performed to understand the discrepancy between TES and GEOS-Chem.

Previous work using the GEOS-Chem model

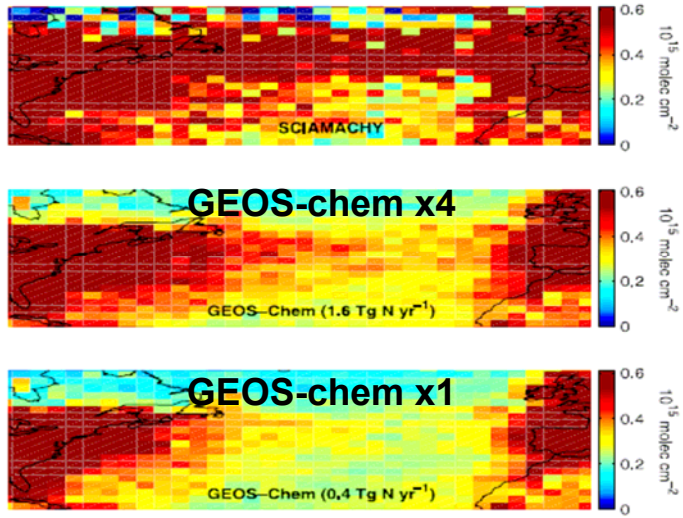
Observations and model simulations from ICARTT campaign over eastern N. America in summer 2004



Hudman et al. [2007]

Observations
GEOS-Chem model (standard)
GEOS-Chem model (lightningx4)

Tropospheric NO2 columns from SCIAMACHY and model in May-October 2004



Martin et al. [2005]

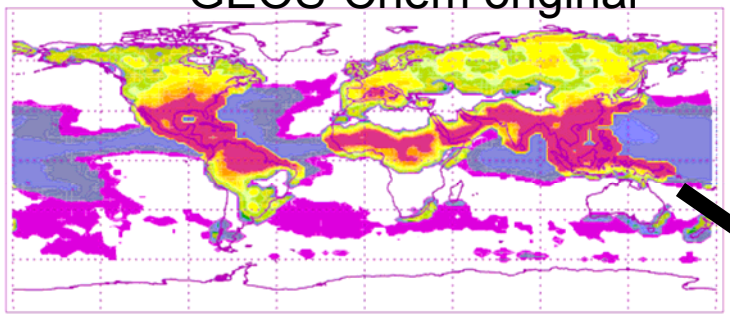
→ These studies had to increase the lightning source by a factor 4 to match NOx and ozone measurements

Possible reason for the discrepancy : distribution of the lightning in the model

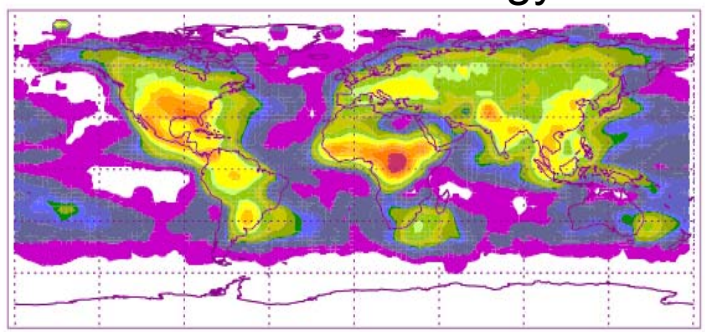
**** Baseline Simulation S1:***

Lightning source scaled to total 6 TgN/yr globally
+ lightning regionally scaled to OTD/LIS climatology

GEOS-Chem original

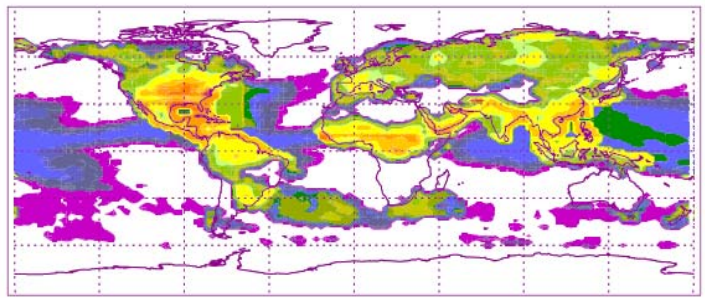


OTD/LIS Climatology



Regional and
Global scaling
to OTD/LIS

GEOS-Chem S1



Flash/km2/yr

Resulting Source : 0.1 TgN in July 2006 over the USA (=260 moles NO /Flash in mean consistent with **Schumann and Huntrieser [2007]).**

**** Simulation S0:***

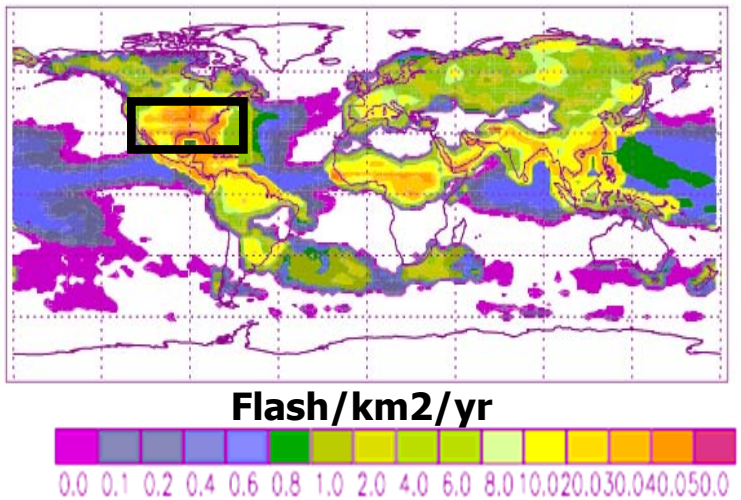
No lightning source over the USA

**** Sensitivity to the distribution of the lightning source***

= Simulation S2:

Lightning scaled to NLDN observations over the USA for July 2006

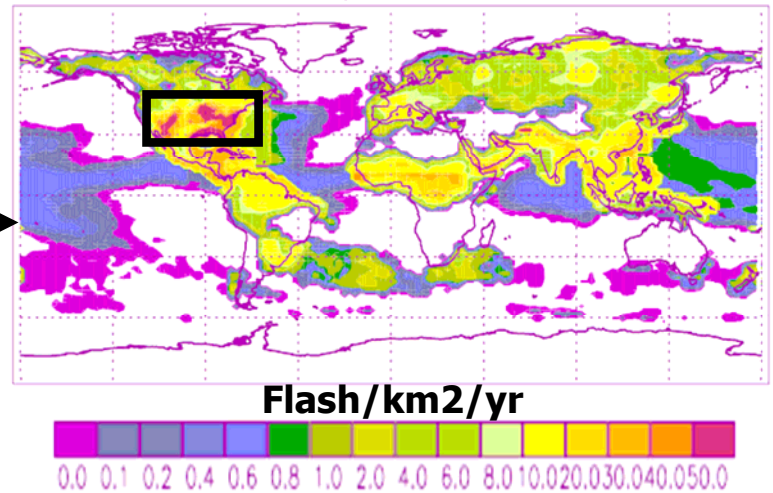
GEOS-Chem S1



Scaling to NLDN data over the US

on daily basis

GEOS-Chem S2



Resulting Source : 0.14 TgN in July 2006 over the USA

IC/CG is from Boccippio et al. [2001]

**** Sensitivity to the strength of the lightning source***

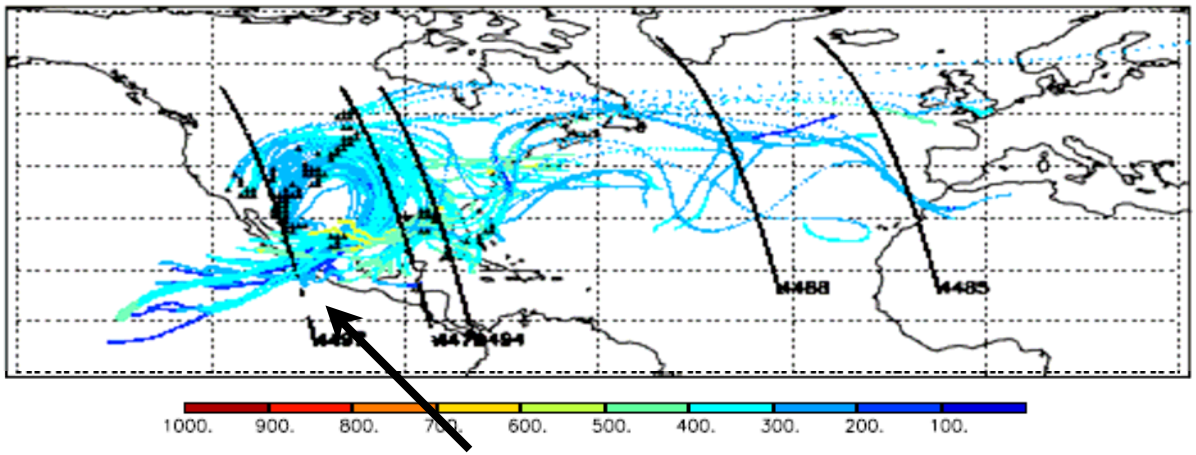
= Simulation S3:

S1 x 2 520 moles NO/Flash in mean close to **Decaria et al. [2005]**

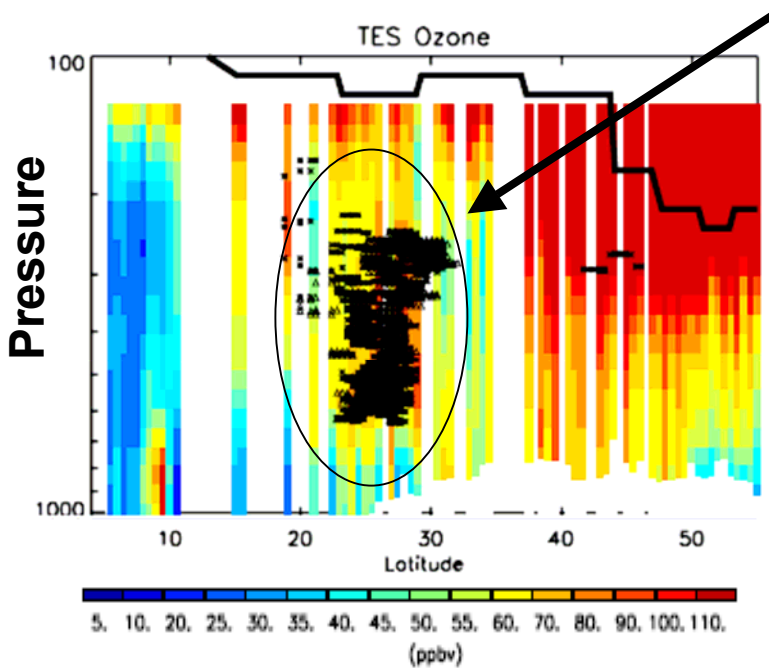
Resulting Source : 0.2 TgN for July 2006 over the USA

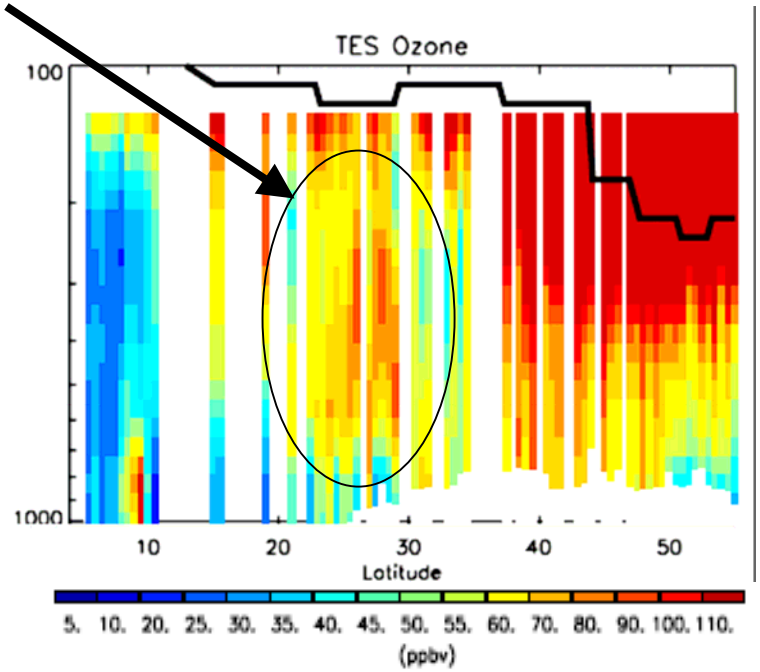
TES Observes ozone enhanced layers influenced by lightning

Hysplit Trajectories from NLDN Flashes 07/08/2006 (subset)



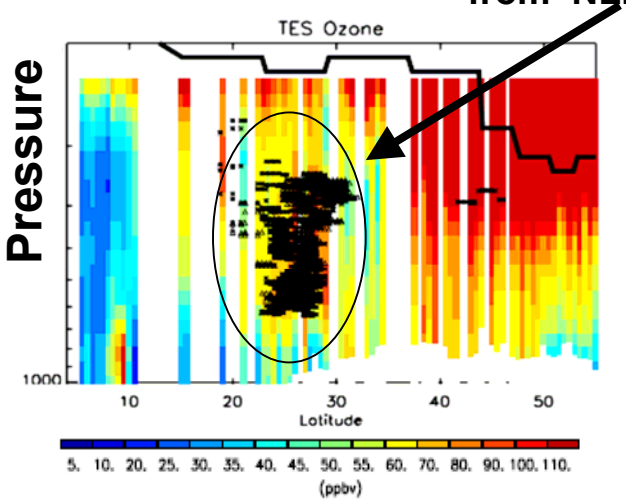
TES Run 4497, 07/12/2006

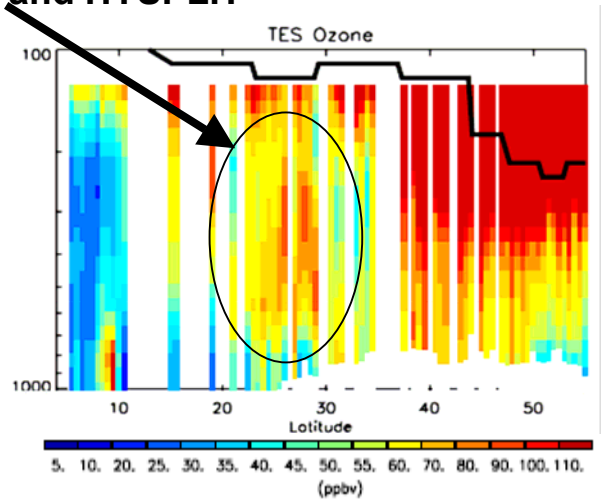




TES/GEOS-Chem Comparison (07/12/06, Run 4497)

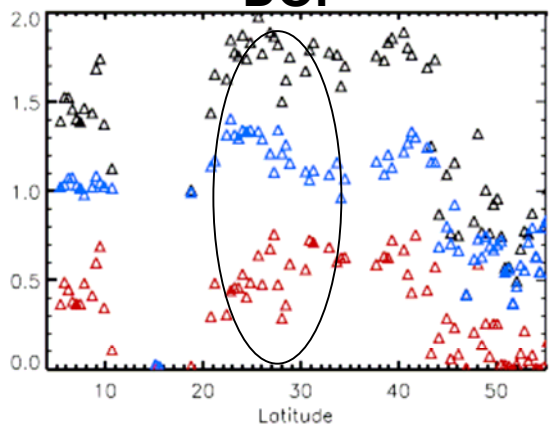
Lightning Influence inferred from NLDN and HYSPLIT

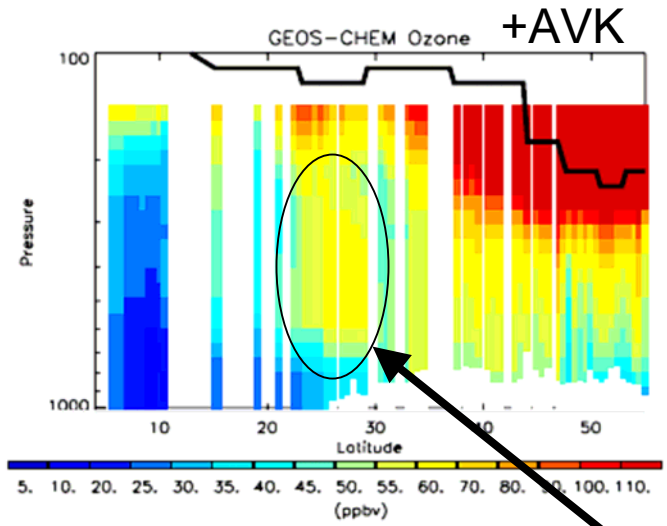


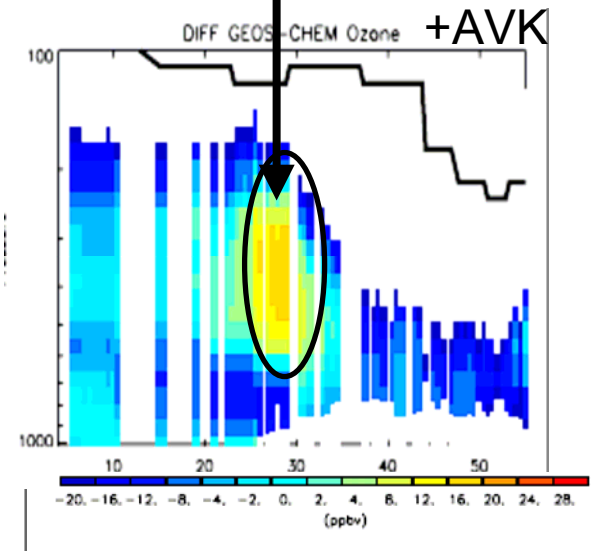


Difference between GEOS-Chem baseline (S1) and without LNOx (S0)

DOF



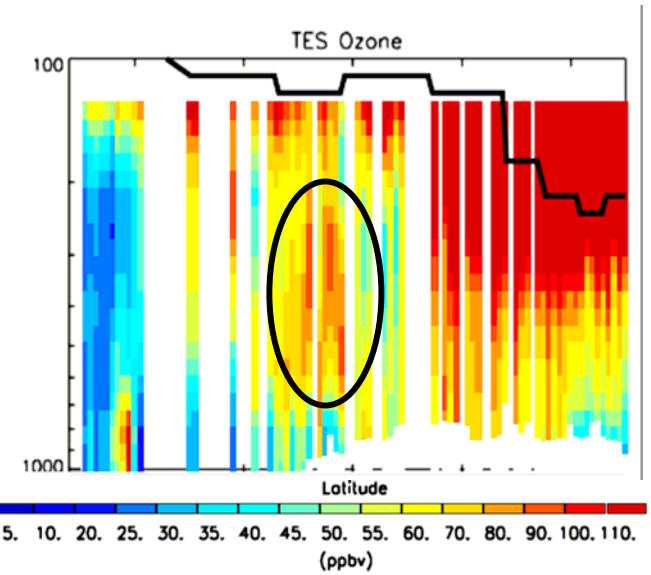


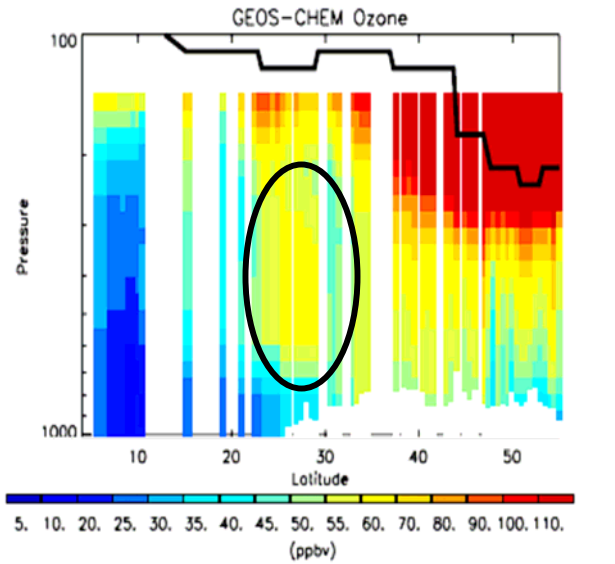


Enhancement also seen in GEOS-Chem (LNOx : 0.1 Tg N/month S1) but TES-GEOS-CHEM > 25 ppbv

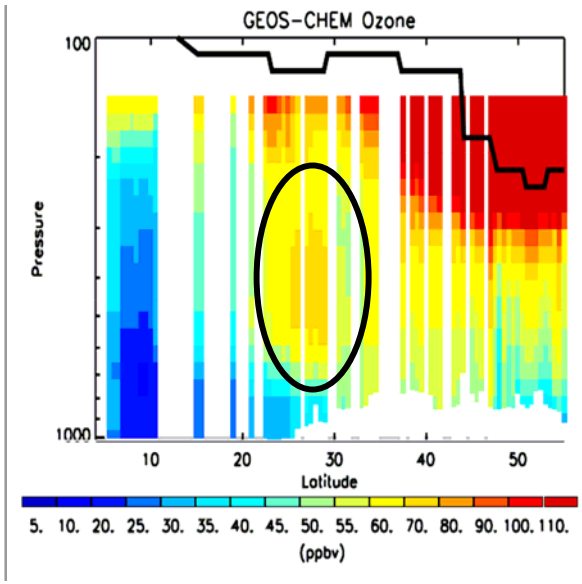
Sensitivity study to the strength of the lightning source

. Test a production of 520 mol NO/Flash more consistent with Decaria et al. [2005]





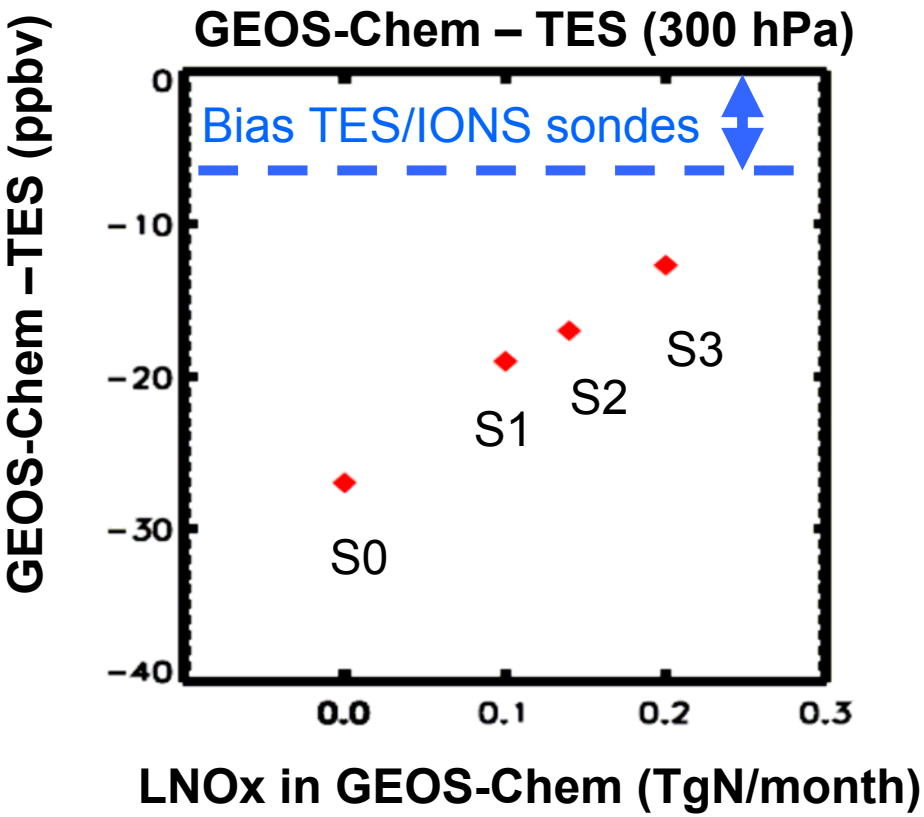
(LNOx : 0.1 Tg N/month S1)



(LNOx : 0.2 Tg N/month S3)

- Better agreement with TES with 0.2 TgN for the lightning NOx source in July 2006 over the USA (simulation S3)

Comparison between TES and GEOS-Chem for TES locations influenced by lightning



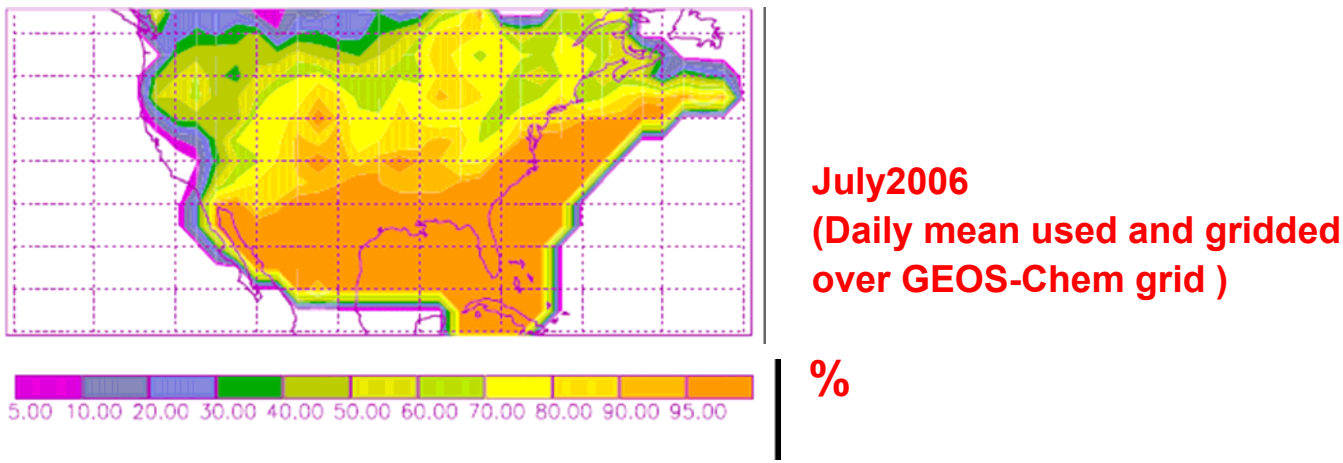
S0 : no lightning source
S1 : Baseline 0.10 TgN/month
S2 : scaling to NLDN
0.14 TgN/month
S3 : S1x 2 520 mol NO/Flash
0.20 TgN/month

- Bias between TES and GEOS-Chem:
Change from 260 moles NO/Flash (S1) **[Schumann and Huntrieser, 2007]**
to 520 moles NO/Flash (S3) **[De Caria et al., 2005]** reduced the bias by 8 ppbv.

Comparison between TES and GEOS-Chem for TES locations influenced by lightning

- Correlation between TES and GEOS-Chem at 300 hPa:
0.4-0.6 depending the latitude,
same for all the simulations even when NLDN lightning distribution is imposed (S2).

P (lightning in GEOS-Chem > 0 / when NDLN lightning >0)



July2006
(Daily mean used and gridded over GEOS-Chem grid)

-> convective events that are influencing the air masses sounded by TES over the US captured by the model

Conclusions

• We show evidence of ozone enhanced layers influenced by lightning in the TES data over the USA in summer 2006 using National lightning Detection Network and Hysplit.

• The GEOS-Chem model confirms the influence of the NOx lightning emissions to the ozone enhancements seen by TES. The model underestimates the intensity (by 19 ppbv in mean) of these ozone enhancement layers .

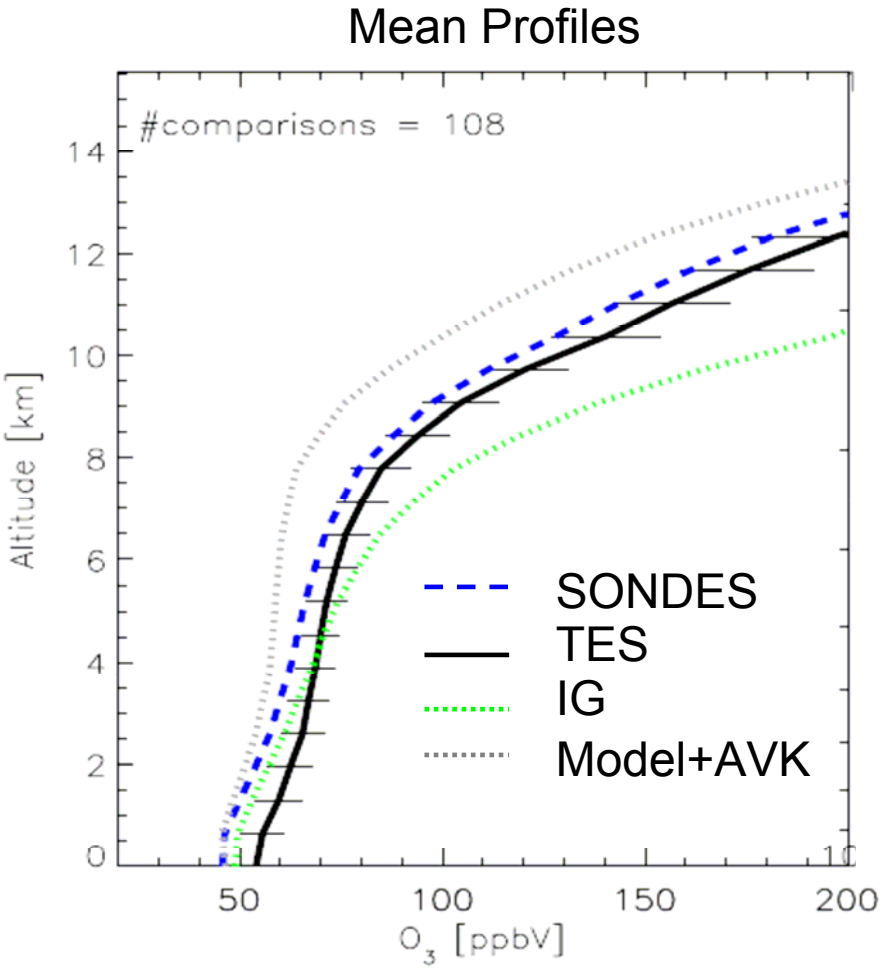
•2 sensitivity studies :

(1) the distribution of the lightning source set to NLDN : does not change the comparison between TES and GEOS-Chem.

(2) increase NO production/Flash from 260 to 520 mol NO/Flash (Decaria et al., 2005) : improves the comparison between TES and GEOS-Chem. The disagreement is reduced from -19 ppbv to -12 ppbv.

• Possible reasons for the remaining discrepancy between TES and GEOS-Chem include the vertical distribution of lightning NOx emissions, Strat-Trop exchange.

Comparison between TES, GEOS-CHEM and IONS data



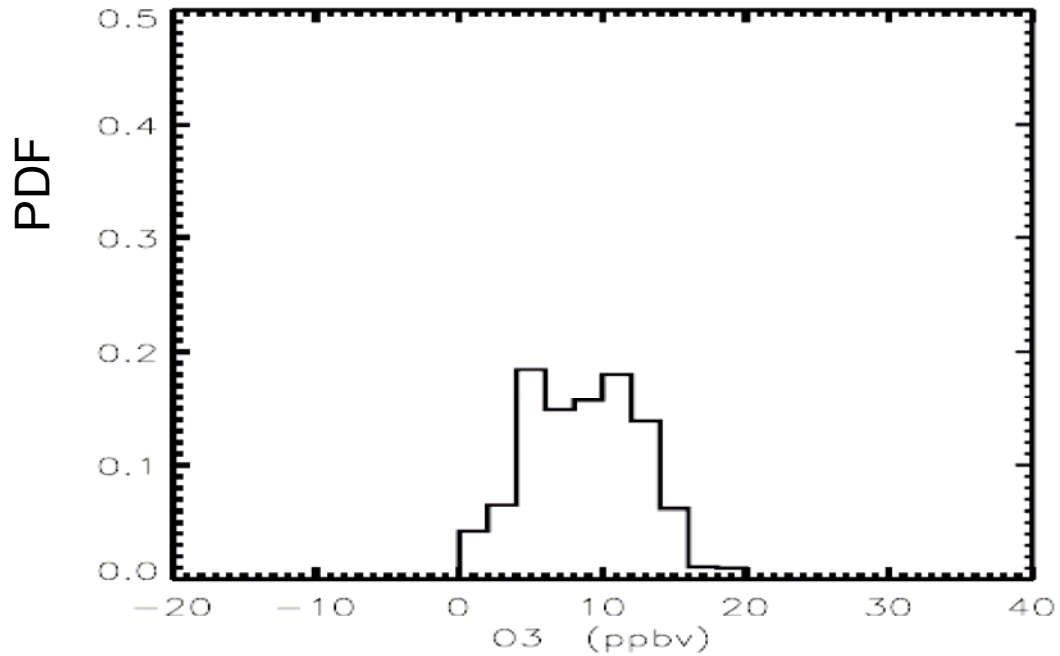
In the upper troposphere :

-Bias between TES- Sondes: 5 to 15 ppbv Worden et al. [2007]

-Bias between GEOS-CHEM - Sondes: -10 to -40 ppbv

-> focus our study at 300 hPa

PDF of ozone differences in GEOS-Chem due to lightning at the TES locations recently influenced by convection



Comparison GEOS-Chem/TES for July 2006

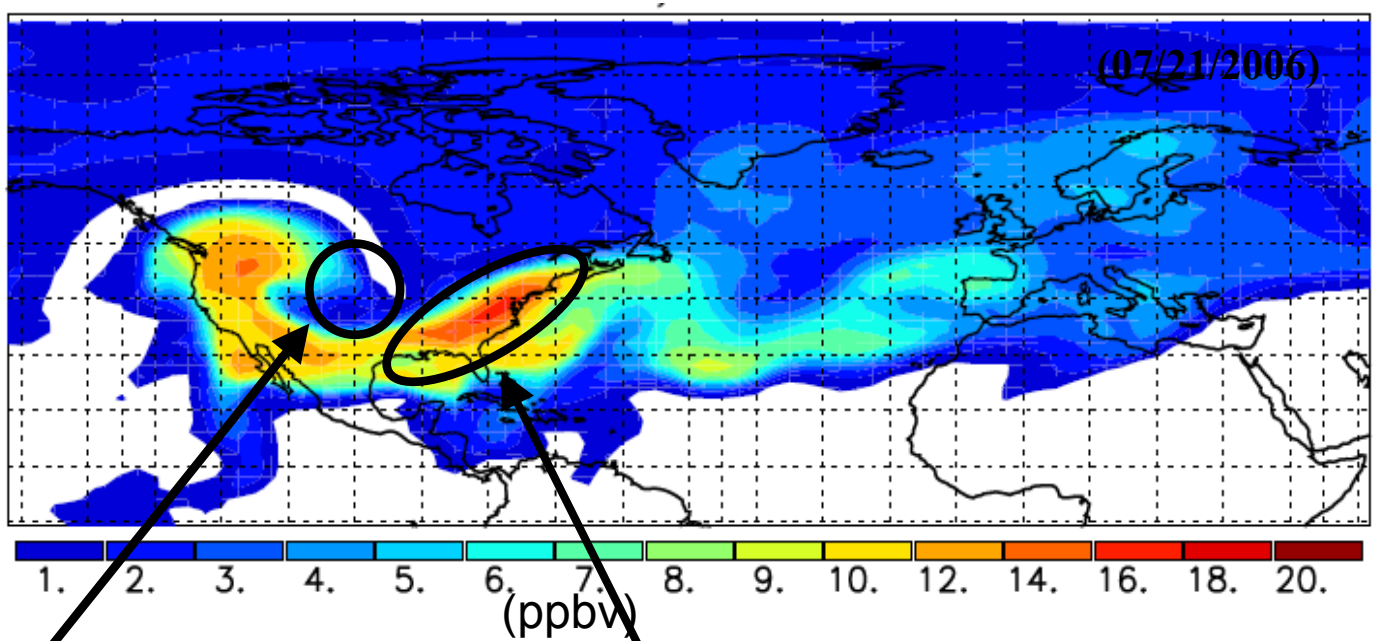
Statistics for the July Step and Stare over the US (78 S&S at 300 hPa)

	Correlation	Bias (ppbv)	RMS (ppbv)
GEOS-Chem (S1) vs TES	0.68	-20	31
A priori vs TES	0.32	25	49

• High correlation between TES and GEOS-Chem (significantly larger than TES/IG)

Testing our understanding of the lightning source

Difference in O3 between the 2 simulations (S1-S0) for a particular day at 300hPa

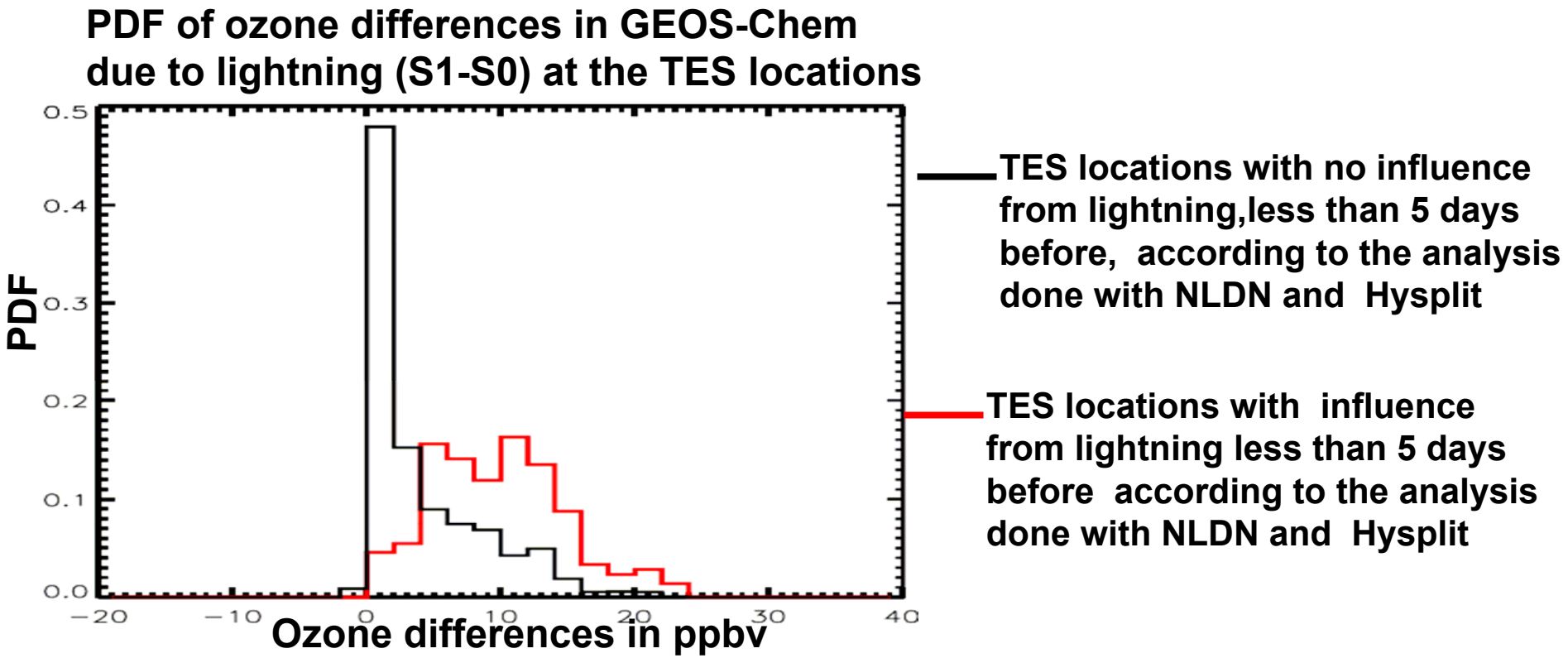


Location with limited influence by lightning

Location strongly influenced by lightning

Is the bias between TES and GEOS-Chem the same for these 2 type of locations ?

Selection of the TES data recently and non recently influenced by lightning



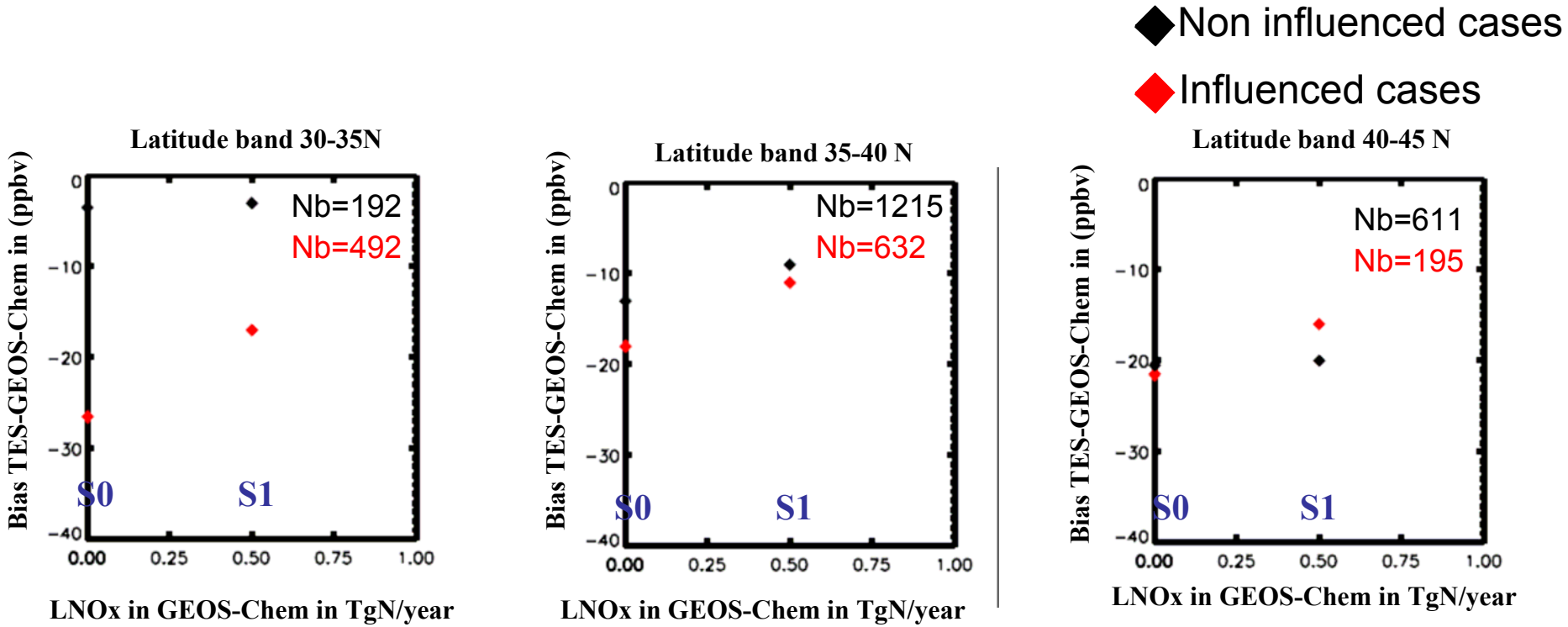
TES data non influenced by lightning :

-TES locations non influenced (with NLDN and Hysplit) and S1-S0 < 2ppbv

TES data strongly influenced by lightning :

-TES locations influenced (with NLDN and Hysplit) and S1-S0 > 10ppbv

Bias for recently influenced or non recently influenced by lightning cases



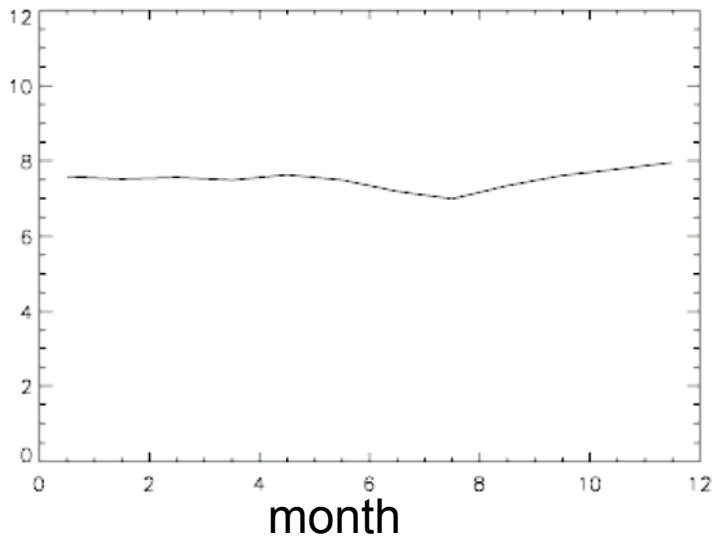
-For cases non influenced by lightning : bias increases with increasing latitude

-For cases strongly influenced by lightning :
For lat > 35N : biases the same in the non influenced and influenced cases

For lat < 35 : the bias in the air masses recently influenced by lightning is larger (15ppbv) than in the air masses non influenced (2ppbv).

NOx lifetime depends on OH

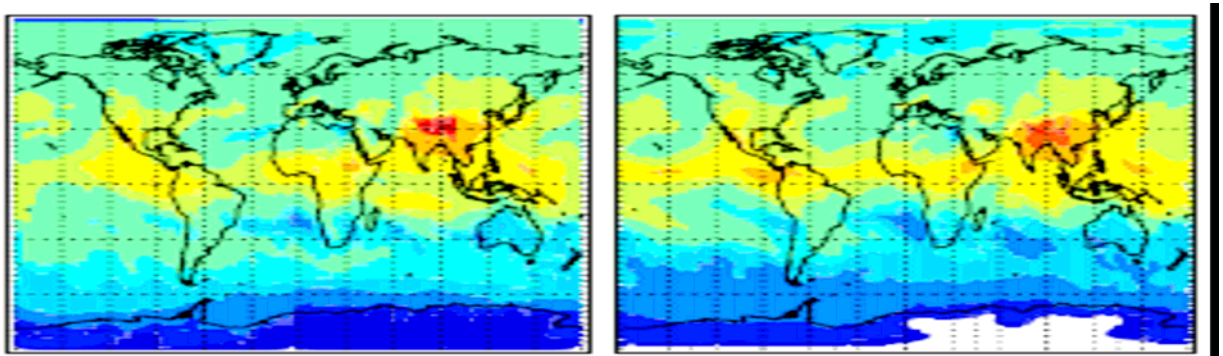
CH4 lifetime in GEOS-chem



7.5 years < 9.6 years (IPCC 2001)
Overestimation of OH

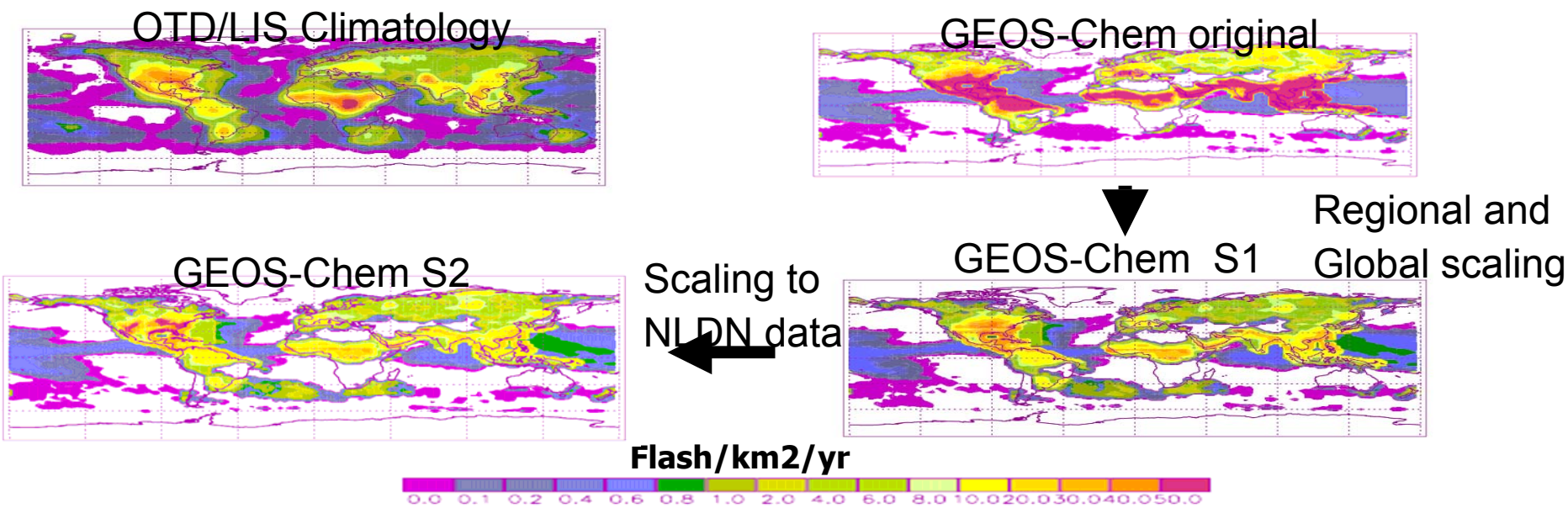
H2O NCEP JJA

H2O GEOS-CHEM JJA



Overestimation Of H2o in GEOS-Chem particularly tropics And DJF

Distribution of the lightning activity in GEOS-Chem for July 2006



4 simulations :

*** S1 lightning source scaled to total 6 TgN/yr globally**
+ lightning regionally scaled to OTD/LIS climatology

Resulting Source totals : 0.5 TgN/year over the USA (=260 moles/Flash in mean)

*** S2 lightning scaled to NLDN observations over the USA for July 2006**

Resulting Source totals : 0.6 gN/year over the USA

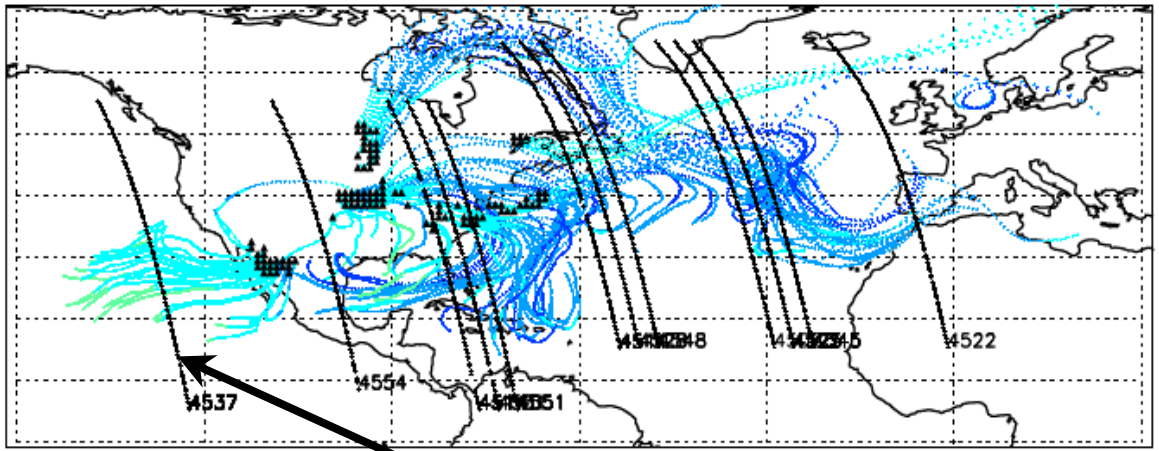
***S3 = S1 x 2 over the USA (Testing K. Pickering recent work)**

Resulting Source totals : 1 TgN/year over the USA (= 520 moles /Flash in mean)

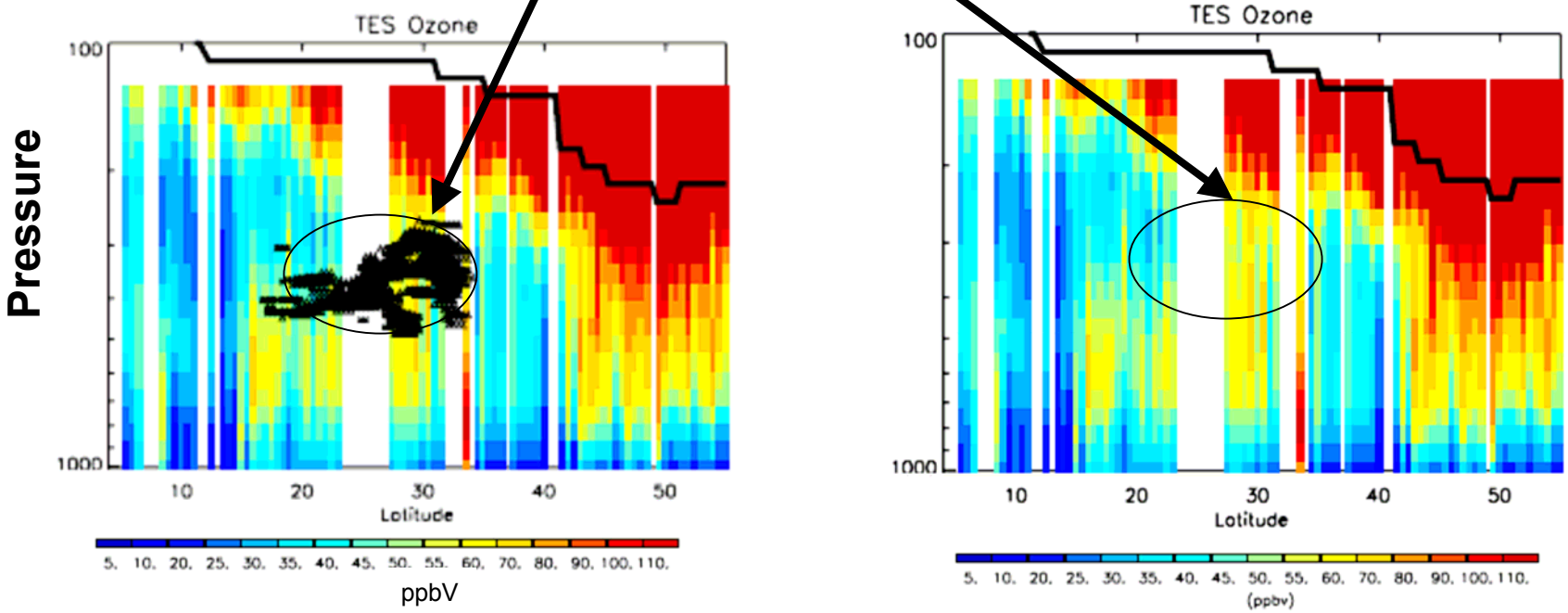
* **S0 lightning source shut off over the USA** (initialized the 1st March 2006 with S1)

Ozone enhanced layers influenced by lightning in the TES data

Hysplit Trajectories from NDLN Flashes 07/14/2006 (subset)

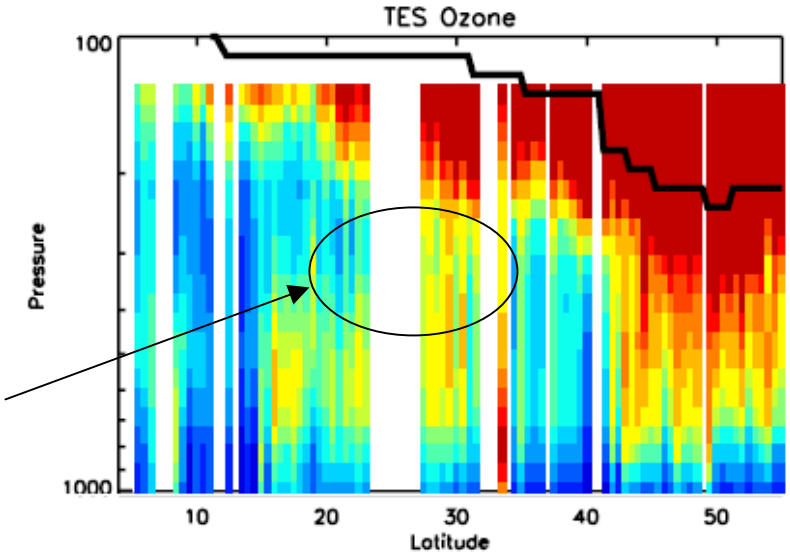


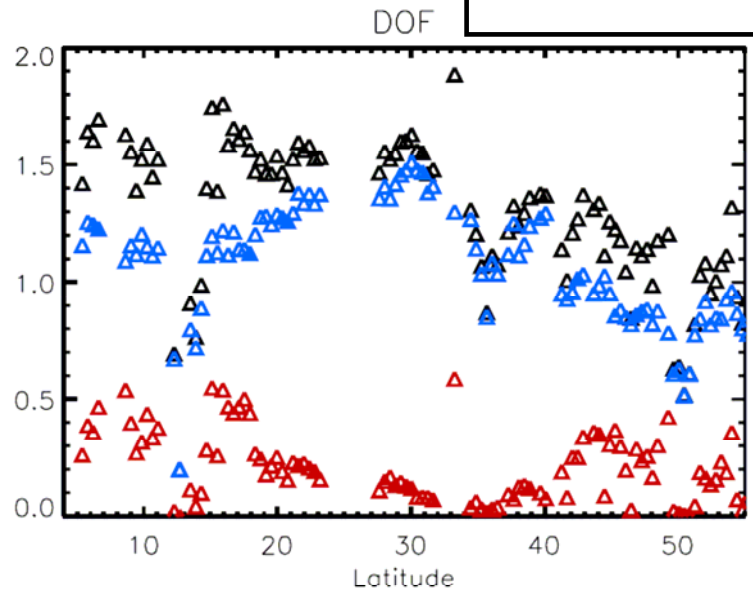
TES Run 4537, 07/16/2006

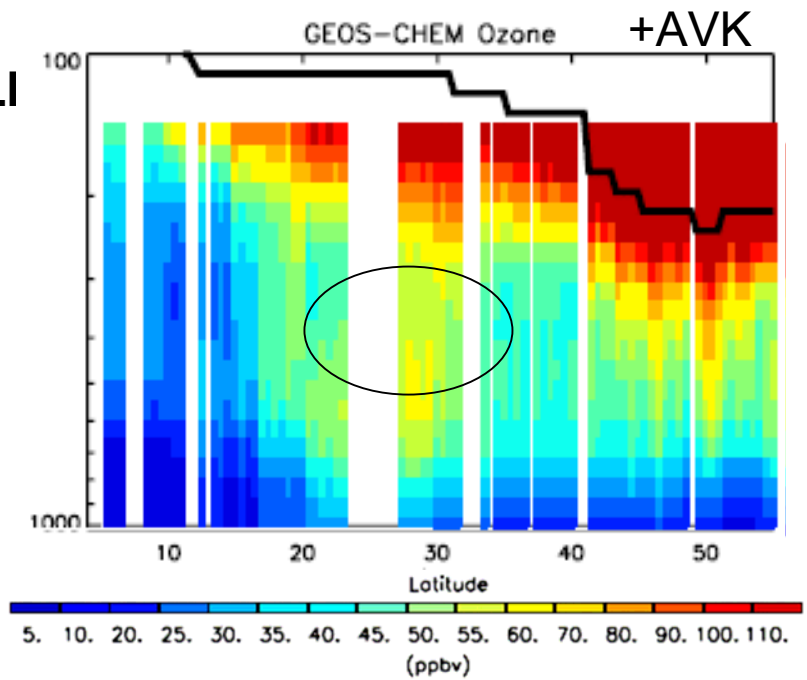


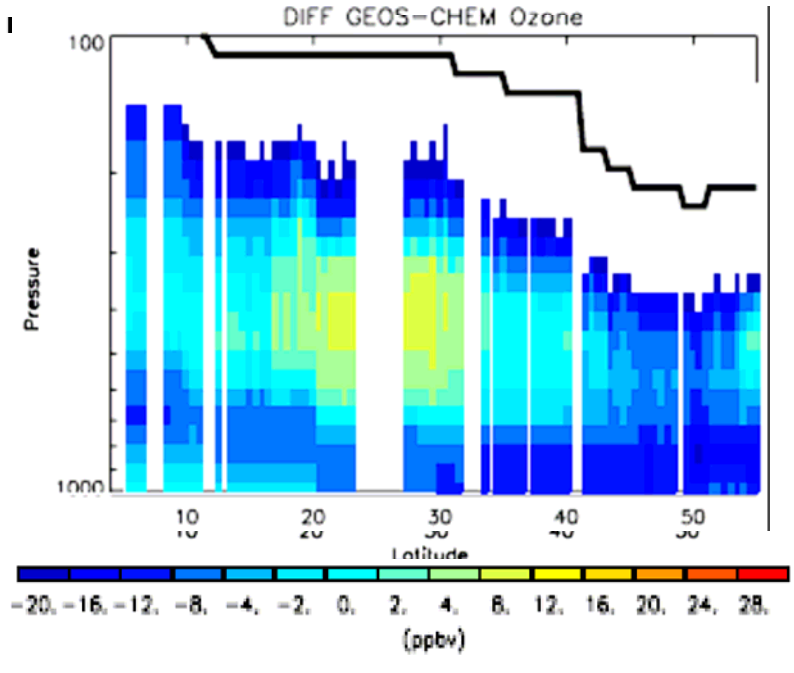
TES/GEOS-Chem Comparison (07/16/06)

Lightning influence inferred from NLDN and HYSPLI









Methodology

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- **Look for the intersection of trajectories with the TES track**
  criteria for coincidences : +/- 1 degree lat/lon, +/- 1 hour

- **Run the Global 3D CTM GEOS-Chem for Jan-August 2006**,
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- **Compare TES and GEOS-Chem prediction** for the cases where lightning influences were found in the TES data.

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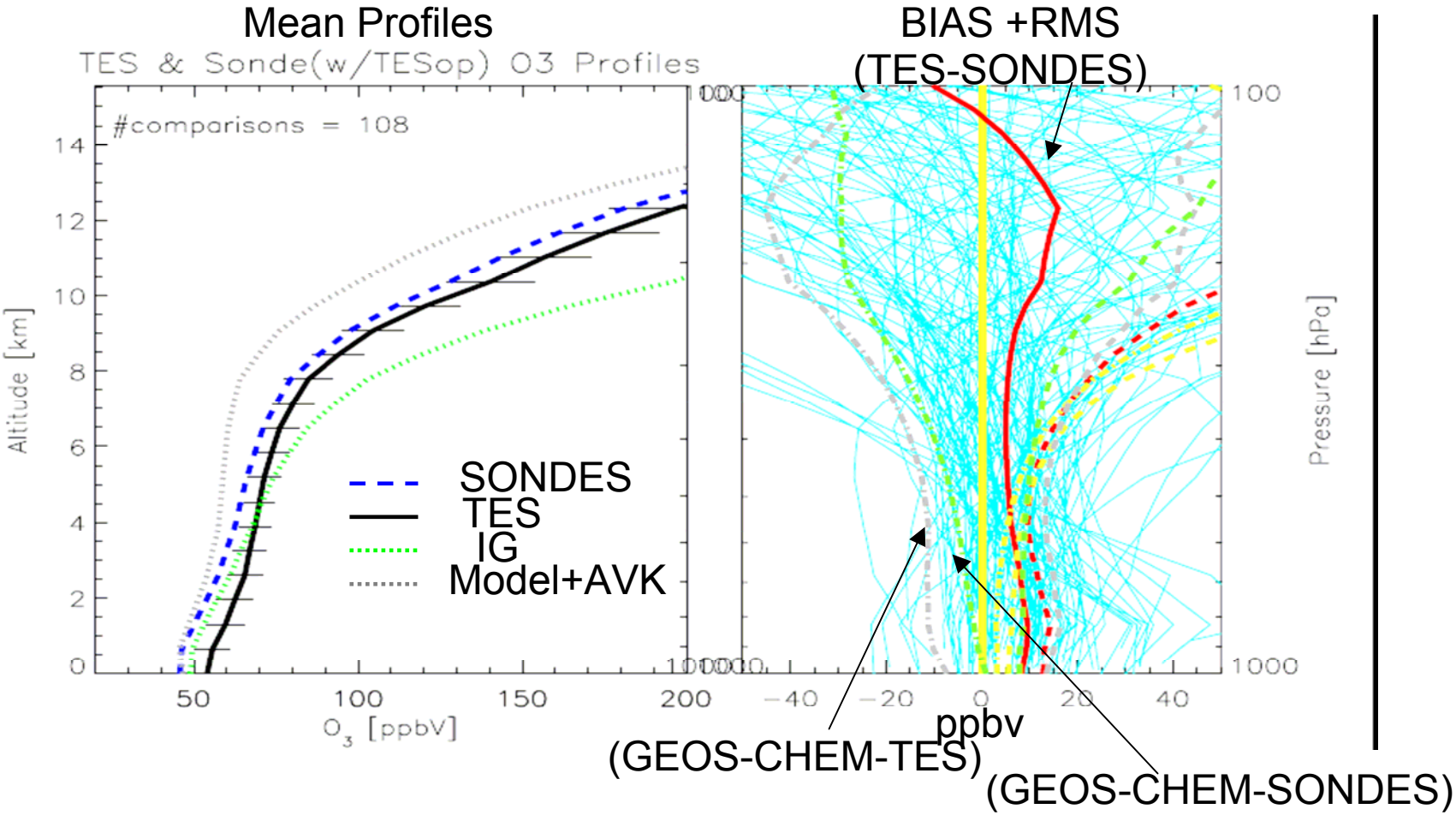

In the upper troposphere :

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-Bias between GEOS-CHEM - Sondes: -10 to -40 ppbv

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Distribution of the lightning activity in different versions of GEOS-Chem for July 2006

Original version

Regional and Global Scaling (this work)